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W.M. Haas, B.D. Alkire
and J.E. Dingeldein

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Winter earthwork construction was observed in three counties in Michigan's Upper Peninsula during the 1975-76 season. These included a state highway in Alger County, a county highway in Marquette County being built essentially to state standards, and a series of county road segments in Ontonagon County for primarily local traffic. In all cases, construction methods are used which exclude frozen soil from the central core of the embankment, with frozen soil permitted in the outer slope zone. This zone must be compacted during over

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warm weather as part of final shaping and cleanup. While all projects were technically successful, construction was halted in early February on one project because it was uneconomical for the contractor to continue. The need for frequent removal of heavy snowfall was one factor in this decision. On another project, the contractor successfully exploited soil freezing to form stable smooth haul roads for his scrapers. In this case, the sand was so clean that hauling would have been difficult if the sand had not been frozen. The road construction in Ontonagon County was done by county road commission employees when their time and equipment were not needed for snow removal. Most of the work consisted of raising the grade of existing roads by 18 inches of non-frost-susceptible soil to minimize frost heaving and loss of bearing capacity. This winter activity resulted in better utilization of county equipment and work crews.

PREFACE

This report was prepared by W.M. Haas, Professor of Civil Engineering, B.D. Alkire, Associate Professor of Civil Engineering, and J.E. Dingeldein, Graduate Research Assistant, of the Civil Engineering Department, Michigan Technological University, Houghton, for the U.S. Army Cold Regions Research and Engineering Laboratory.

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

As part of a continuing study of winter earthwork, the authors observed construction activities at several highway projects during the 1975-76 winter season. The purpose of this study was to identify and document (a) construction practices appropriate and peculiar to winter work, (b) physical constraints that mitigated against winter earthwork, such as temperature and other climate-related factors, soil type, and soil moisture, and (c) institutional or organizational constraints.

The projects were visited several times during the winter to observe and photograph working conditions and construction methods. Information was also obtained by interviewing project engineers and construction superintendents. In some cases, the in-place density of completed fill sections was determined, and samples were taken for particle size analysis. During the following spring and summer, the projects were revisited to observe final shaping operations.

All the projects are located in the western half of the Upper Peninsula of Michigan. Two projects, one in Marquette and one in Alger County, are major jobs built in accordance with Michigan's Standard Specifications for Highway Construction (1975), and provided an opportunity to observe typical Michigan winter construction activity. The third project, located in Ontonagon County, is quite different from the other two. Actually, it is a series of rather small projects spread out over the entire county. The roads carry only local traffic, and are on the county road system rather than the state. They are kept open to traffic while construction proceeds. The height of embankment is often no more than 1.5 feet, and hardly ever is more than 5 or 6 feet, and then only for short distances. They are constructed with a minimum of supervision and inspection.

STANDARD SPECIFICATIONS

Earthwork, as defined by the Michigan Department of State Highways, consists of all work required to construct the earth grade in accordance with specifications and in conformity with line, grade, and typical sections shown on the plans. This definition says nothing about when earthwork is to be allowed. However, specific sections within the specifications place restrictions on winter earthwork that tend to make it unattractive to the contractor whose work is progressing on schedule.

Examination of the specifications reveals the underlying belief that no frozen soil should be included in any embankment area constructed under density control. For example, it is required that the embankment not be placed on frozen soil and no frozen soil be placed in the "core" of the embankment, the core being defined by the embankment top and bottom surfaces and by lines on a 1 on 1 slope downward and outward from the shoulder points. However, as embankment slopes are generally no steeper than 1 on 2 and are often flatter, there is usually a significant portion of the embankment in which frozen material may be placed. When this is done, the preferred method is to build up the core (with unfrozen material) to a higher elevation than the side zones where the frozen material is placed, as shown in Figure 1.

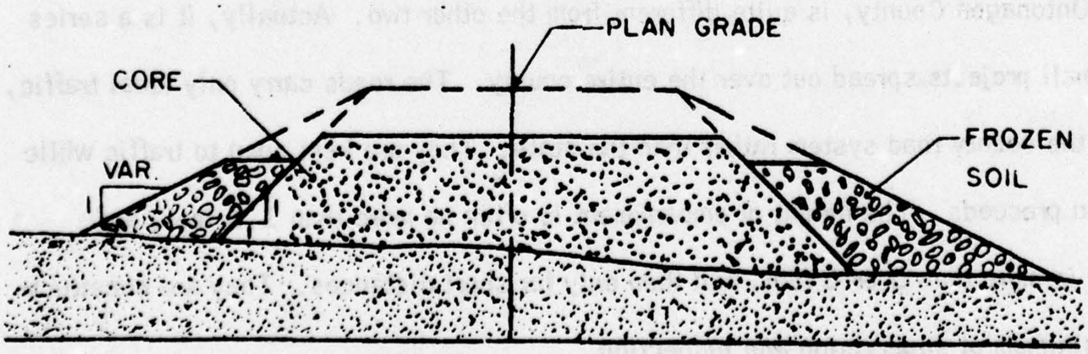

Figure 1 - Embankment Core Concept Used in Winter Earthwork

The specifications also require removal of any frozen soil on partially completed slopes. This means that at the beginning of each day's work, that portion of the previous day's embankment which froze during the night must be removed before additional fill may be placed. This material, plus frozen material from the borrow pit or other areas of excavation must be placed outside the core, and if the frozen soil cannot be disposed of properly, grading operations must be discontinued.

Not only do the specifications control placing frozen soil in embankments but they also stipulate the method of payment for removal of frozen soil. Generally, removal of frozen soil is not a pay item, but borrow to replace the frozen material is a pay item. Also, when removing frozen top-soil from beneath the embankment slope lines the excess material removed due to soil freezing is not allowed as excavation, nor is any compensation allowed for any ripping that might be required. The same philosophy is used for removal of frozen soil that develops on a partially completed embankment.

Contract administration also influences the feasibility of winter earthwork. In Michigan, the "work day" concept is used to determine contract duration and assessment of liquidated damages for failure to complete the project within the specified time. A work day is defined as any day it is possible to effectively carry on work on the controlling operation, exclusive of Saturday, Sunday and recognized holidays. Work days are not charged when operations on the controlling item are suspended by the department, and in most contracts work days will not be charged to the contractor during the winter months. The dates defining the beginning and ending of winter vary over the state and are somewhat at the discretion of the engineer. This allows for exceptional weather conditions (favorable or unfavorable) during the project period. For the Upper Peninsula, the usual shut-down date is November 15 and start-up is April 15. Thus, if a contractor elects to work during

the winter, he has the opportunity to get a slow project back on schedule, or even to get ahead of schedule. Although this option seems attractive, the provisions of the standard specifications must be met. As a result of these "winter rules" along with other factors, contractors generally prefer to shut down for the winter.

CLIMATIC CONDITIONS

Michigan's Upper Peninsula is long and narrow and is bounded on the north by Lake Superior along its entire length. The western half of the peninsula, the study area, is heavily wooded and rises to an elevation between 1000 and 2000 feet above mean sea level. The close proximity to Lake Superior has a substantial influence on the weather and causes a retarding effect on arrival of both winter and spring as well as a moderation of the temperature extremes typical of a mid-continent location. However, the lake effect does contribute to substantial snowfall and some of the largest snowfalls east of the Rocky Mountains occur within the area. Average annual snowfalls of over 100 inches are common and the single season record is close to 300 inches at a location in the northwest portion of the Upper Peninsula.

The general climatic conditions of the Upper Peninsula are also apparent on a more localized scale. Of the three projects observed in this study, one is located adjacent to the lake (Alger County); one is close to the lake, but inland (Marquette County); and the other project was generally located some distance from the lake (Ontonagon County). Temperature and snowfall at each of these sites reflect their proximity to the lake.

To develop a better feel for climatic conditions and their effect on construction

activities, Figures 2 and 3 have been developed from published weather data. In Figure 2 a contour map of average January temperature is shown. January was selected because it is typical of the winter months and shows regional temperature variations that are characteristic of the area. It can be seen that the interior locations have lower average temperatures and, in fact, the three or four degree difference in average temperature translates into a substantial number of degree-days when considered over an entire winter. More specific indications of temperature through out the winter also appear in Figure 2. The stations selected for use in this figure are generally close to the project areas and should approximate conditions at the project sites. The thirty-year average and the 1975-76 average are plotted together to develop a feel for the relative severity of the work conditions during the winter 1975-76. It can be seen that temperatures experienced during the winter construction season of 1975-76 were typical of an Upper Peninsula winter and should not bias the results of observations made during this project.

Because snowfall may be a prime factor in continuance of winter construction, Figure 3 was developed to supplement the information shown in the previous figure. It can be observed that snowfall during the winter of 1975-76 was heavier than normal, but that during some months it was below normal.

PROJECT OBSERVATIONS

The general framework for construction activities in the Upper Peninsula has been discussed above. The observational program conducted during the fall, winter, and spring of 1975-76 saw these practices carried through by representatives of the state, counties and contractors that participated in the projects. Each of the projects was unique and is discussed separately with primary emphasis on reporting observations

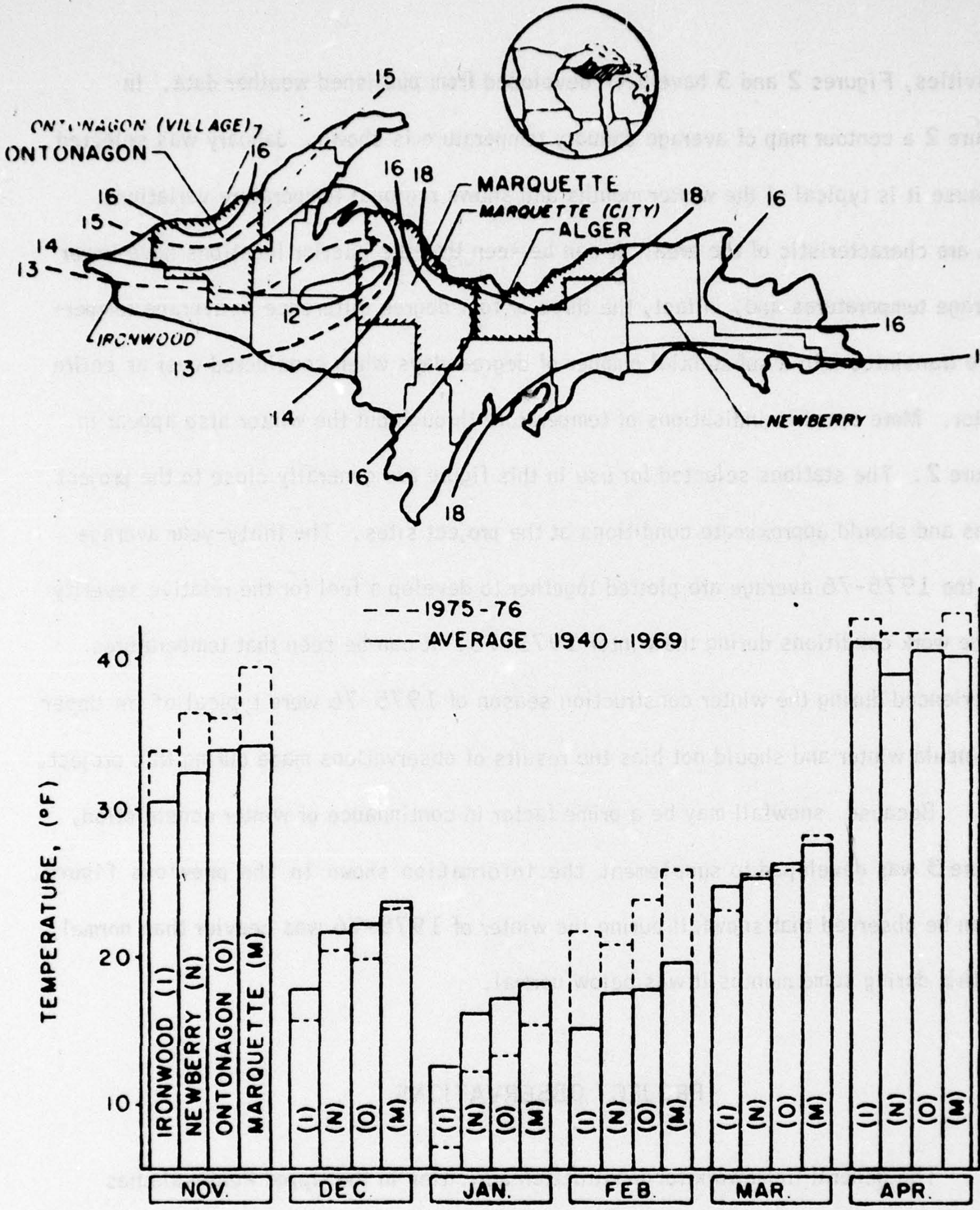

Figure 2 - Top - Average January Temperatures in Michigan's Upper Peninsula, ^{o}F, 1940-1969
Bottom - Monthly Temperatures at Four Stations

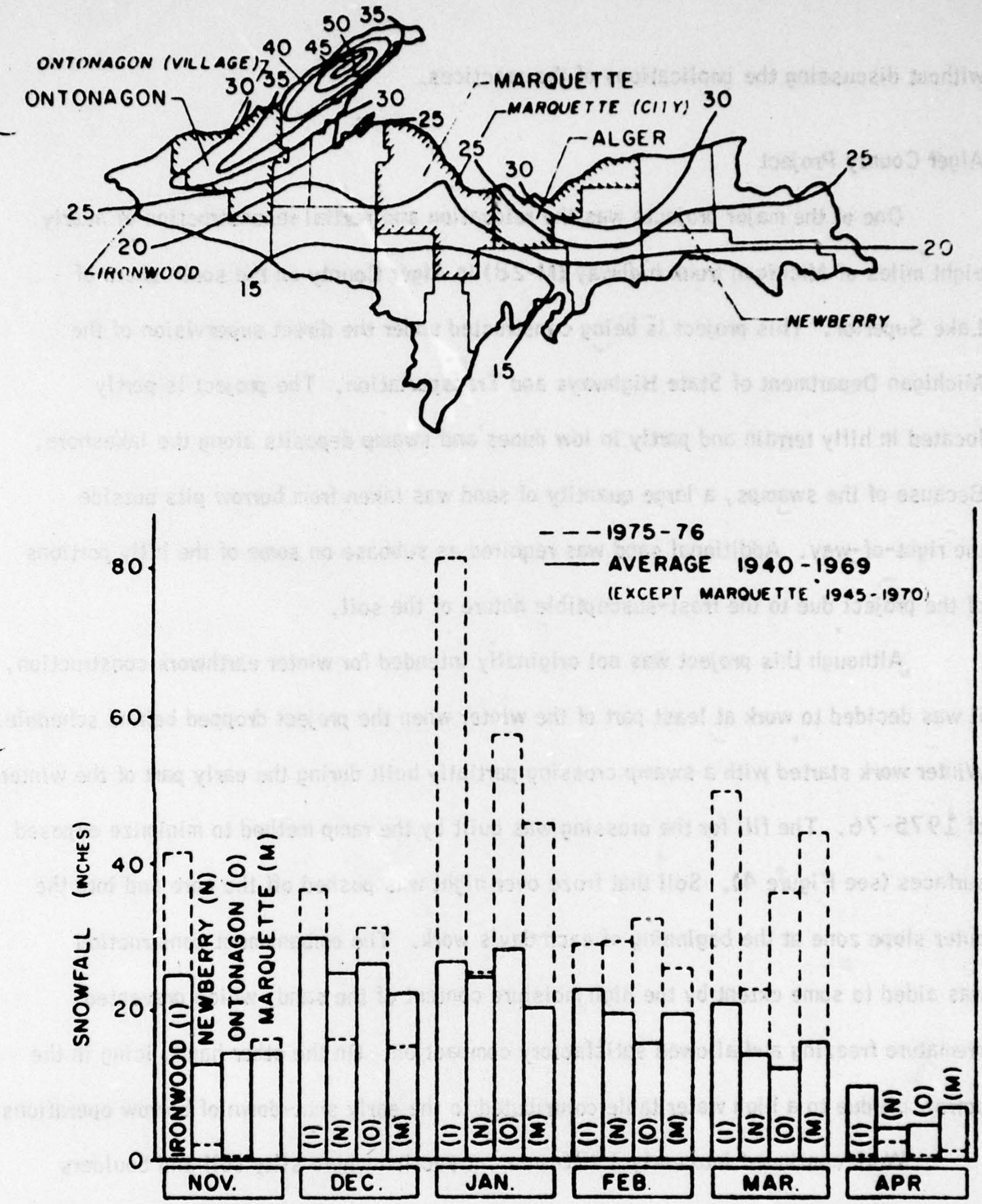

Figure 3 - Top - Average January Snowfall in Michigan's Upper Peninsula, inches, 1940-1969
Bottom - Monthly Snowfall at Four Stations

without discussing the implications of the practices.

Alger County Project

One of the major projects was the relocation and partial reconstruction of nearly eight miles of Michigan trunk highway (M-28) in Alger County on the south shore of Lake Superior. This project is being constructed under the direct supervision of the Michigan Department of State Highways and Transportation. The project is partly located in hilly terrain and partly in low dunes and swamp deposits along the lakeshore. Because of the swamps, a large quantity of sand was taken from borrow pits outside the right-of-way. Additional sand was required as subbase on some of the hilly portions of the project due to the frost-susceptible nature of the soil.

Although this project was not originally intended for winter earthwork construction, it was decided to work at least part of the winter when the project dropped behind schedule. Winter work started with a swamp crossing partially built during the early part of the winter of 1975-76. The fill for the crossing was built by the ramp method to minimize exposed surfaces (see Figure 4). Soil that froze over night was pushed off the core and into the outer slope zone at the beginning of each day's work. The embankment construction was aided to some extent by the high moisture content of the sand, which prevented premature freezing and allowed satisfactory compaction. On the other hand, icing in the borrow pit due to a high water table contributed to the early shut-down of borrow operations.

Work continued into early 1976 in a cut section where silty soil and boulders were removed. In this area snow was permitted to remain on the work area until excavation was actually started. At the beginning of work each morning, the expected cut for the day (usually about two stations), was stripped of snow, then the boulders and soil were removed by a rubber tired loader and a fleet of off-road dump trucks. Although the

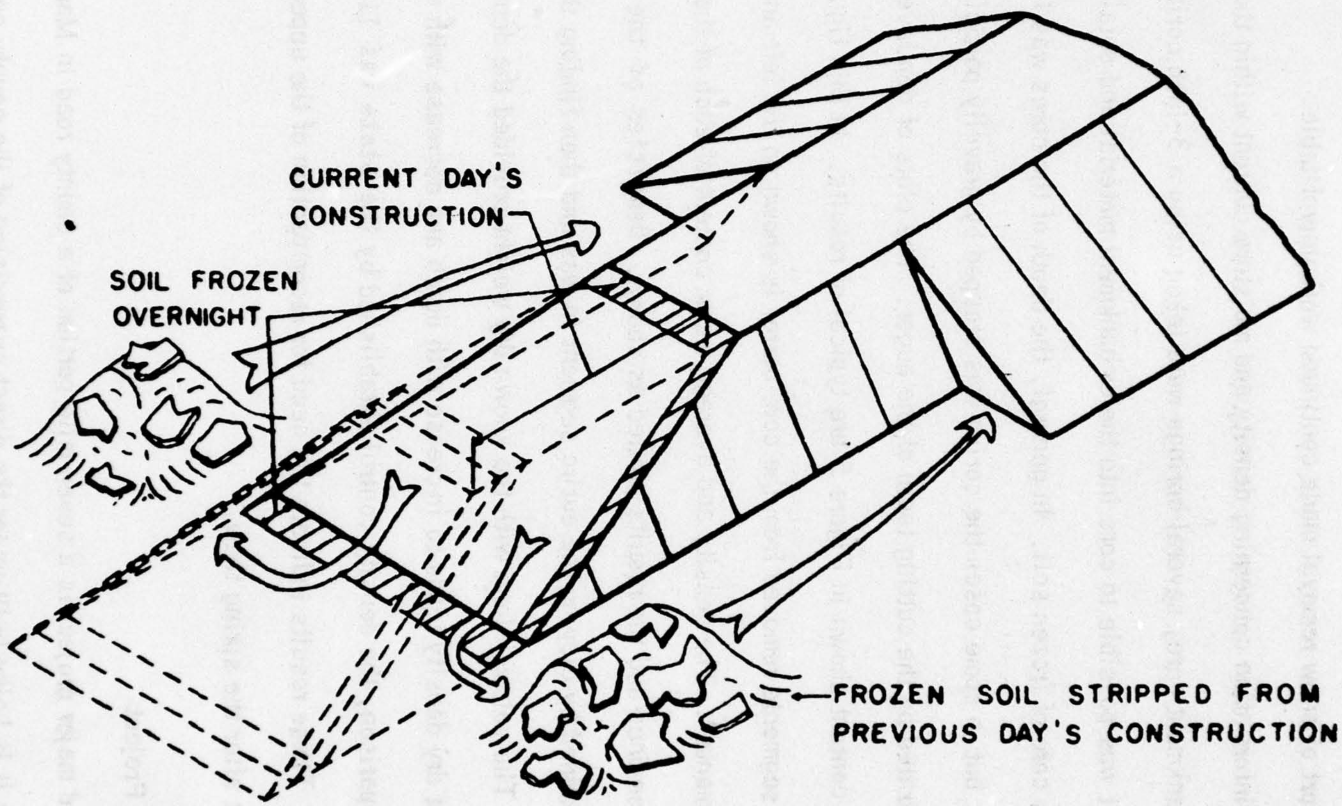

Figure 4 - Constructing an Embankment by the Ramp Method to Prevent Freezing of Fill Before Compaction is Complete

excavated material was not frozen, it was not considered acceptable for the core and was placed in the outer slope zone. This work was discontinued in mid-February when the daily effort of snow removal made continued work unprofitable.

To obtain information concerning density and moisture content within the soil placed in the embankment core, several borings were taken using a 3-inch coring auger. With this device it was possible to core into the embankment material and obtain a more or less continuous core of frozen soil. In general, the depth of the cores was limited to the depth of frost, but in some cases the coring was stopped by gravelly particles that could not be penetrated by the cutting teeth of the auger. The plots of depth versus density and water content shown in Figure 5 are typical of results. In this figure the size of the intact segments removed from the core barrel is shown on the left and is labeled "core segments". The density and average water content of each of the intact segments was determined and the results plotted as shown. Densities of the core segments were obtained by dipping the entire segment in wax and then finding the volume by submergence. The volume along with the known dry weight provided the density. It can be seen that dry density tends to increase with depth and decrease with moisture content. For comparison, the density control established by the State was 110 pcf at 10% moisture. These results indicate the need for recompaction of the upper zone of the embankment after the spring thaw.

Marquette County Project

The second major project is a seven mile portion of a county road in Marquette County. Although it is being built under the direct supervision of the county engineer, it is being relocated (in part) and rebuilt to essentially the same standards as the state trunk system. With the exception of a few short stretches of swamp, the entire length

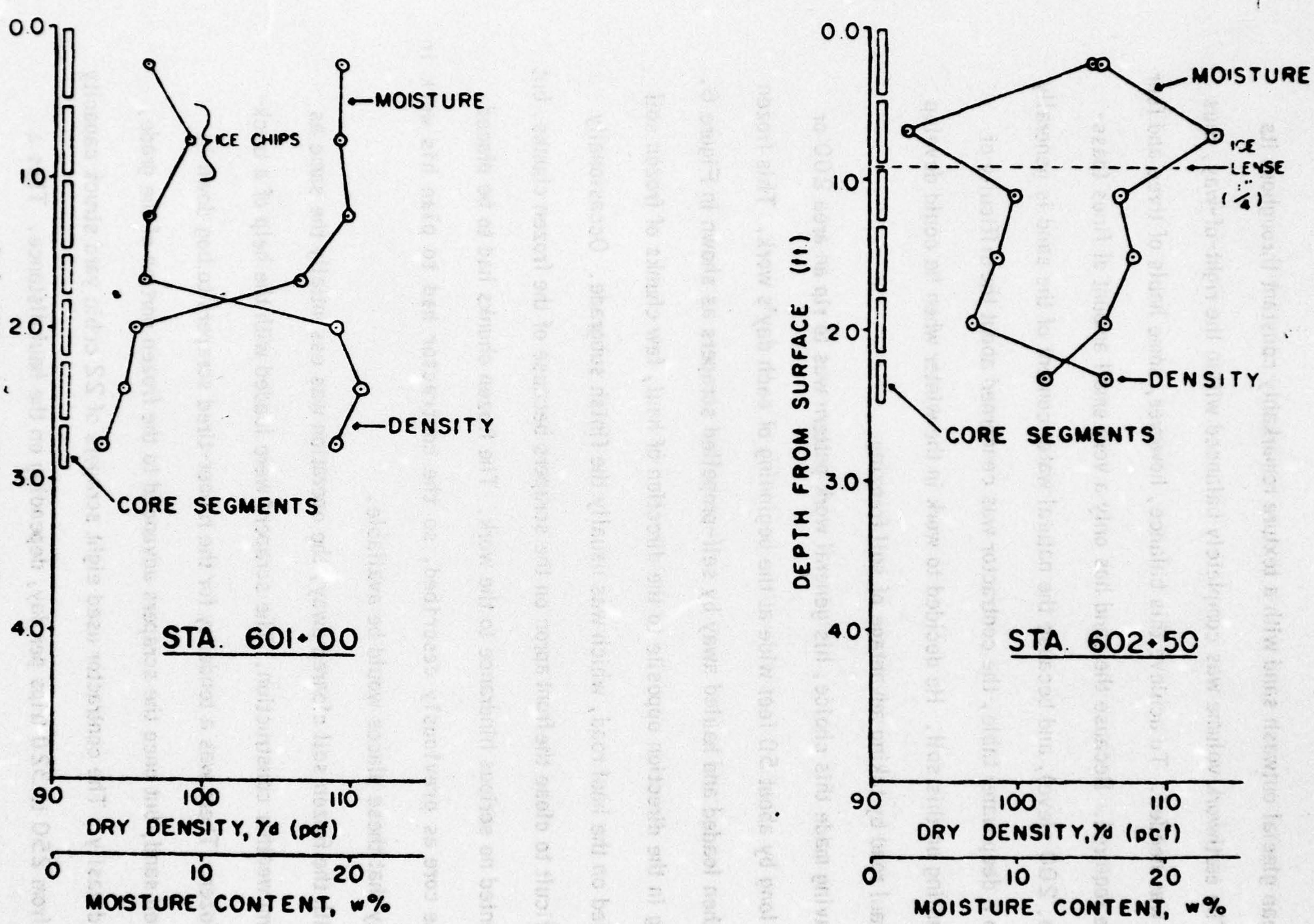

Figure 5 - Density and Moisture (Ice) Content of Embankment Constructed in Winter (Alger County)

is in a clean glacial outwash sand with a texture remarkably constant throughout its length. The earthwork volume was completely balanced within the right-of-way, thus no borrow was needed. To achieve this balance, however, some hauls of three and four miles were required. Because the sand has only a very small amount of fines (passing the No. 200 sieve), and because the natural water content of the sand is generally low due to a deep water table, the contractor was concerned about the difficulty of summer hauling on this soil. He decided to work in the winter when he could develop a stable haul road by taking advantage of soil freezing.

Having made this choice, his general work pattern was to rip an area 200 or 300 feet long by about 50 feet wide at the beginning of each day's work. This frozen soil was then loaded and hauled away by self-propelled scrapers as shown in Figure 6. By loading in the direction opposite to the direction of haul, few chunks of frozen soil were spilled on the haul road, which was usually the finish subgrade. Occasionally it was difficult to close the front apron on the scrapers because of the frozen chunks, but this presented no serious hindrance to the work. The frozen chunks had to be placed outside the core as previously described, so the contractor had to plan his work in such a way that these places would be available.

With the frozen soil cleared away, the operation was essentially the same as during warm weather construction. The scrapers were loaded with the help of a track-mounted dozer. There was a tendency for the rubber-tired scrapers to bog down in the unfrozen sand, but once the scrapers advanced to the frozen portion of the grade, they moved easily. The contractor used eight scrapers of 22 cubic yard struck capacity and made from 250 to 320 trips per day, depending on the haul distance. Thus a typical day's production was about 6000 cubic yards.

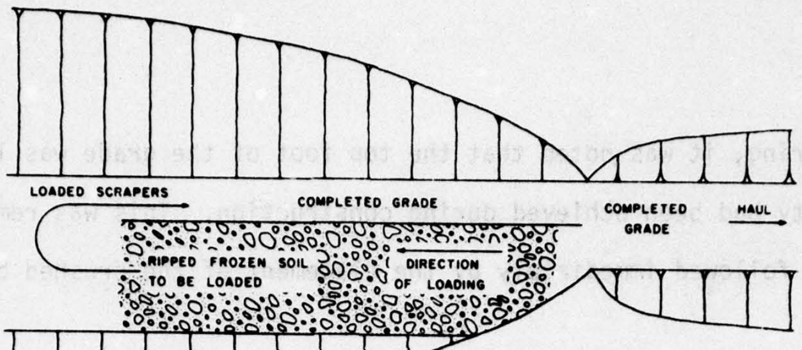

Figure 6 - Pattern for Loading Ripped Frozen Soil with Scrapers.

To facilitate starting the machines each morning, each scraper was parked overnight at a propane tank. This provided fuel for internal heaters which kept the crankcase oil warm, as well as the fluid for the hydraulic controls. With this protection, there was virtually no morning delay for start-up, so that the machines were used efficiently.

The only equipment problem observed was a broken hydraulic control hose on the dozer-mounted ripper. This happened when a large frozen slab came up through the support yoke and struck the hoze. The dozer operator stated that ripping frozen soil on this project was about the same as ripping sandstone.

During the time this project was active, there was little snowfall. This of course meant that there was little insulation to retard frost penetration, and frost depths of up to 5 feet were observed. On the other hand, it was an advantage as the accumulated snow did not present a storage problem later in the winter. As a result of generally favorable conditions and good management by the contractor, more than 90 percent of the earthwork was done during winter conditions. The remainder was not done until spring because the depth of ripping would have exceeded the depth of cut, thus requiring that unfrozen material be brought back to obtain the design grade.

In the spring, it was noted that the top foot of the grade was loose, although density had been achieved during construction. This was remedied by compaction, followed immediately by the placement of the crushed base course.

To determine if frozen material had been incorporated into the core section on this project, a trench was dug in the embankment slope to such a depth that it intersected a 1:1 line from the shoulder. (See photos 29 and 30 in the Appendix). The sand in this trench was then checked for the presence of frozen soil. Some frozen soil was seen in isolated places, as in Photo 31. However, these occurrences were all found to be outside of the core area as defined by a 1:1 line from the shoulder.

In addition, the sand in the slope zone was recompacted in the process of backfilling the trench. This insured that the density was the same as in the core, and was considered to be good insurance against settlement of the slope. This recompaction was done with a bulldozer (see photo 32) which also carried the ripper used for breaking up frozen soil.

Ontonagon County Project

The projects in Ontonagon County are different in many ways from those previously described. All these projects are on county roads which carry only minimal traffic volume, and were built by Ontonagon County highway department personnel, using county-owned equipment. Because much of Ontonagon County is covered by a frost susceptible

varved clay the purpose of these projects is to upgrade existing roads so that they will be more capable of resisting the effects of frost action and be able to support wheel loads during the spring break-up. It has been found by experience that 18 inches of granular material is quite effective in controlling frost effects on roads of this service category, even though the frost penetrates five or six feet. An additional benefit from placing the granular material is that this often results in raising the gradeline above the surrounding land, permitting the wind to blow much of the snow off the road, thus simplifying snow removal.

This group of projects is also distinctive in that a similar program of road improvements has been carried out during the winter months for several years, and it is expected to continue into the future. Also, the work was done by the county's own men and equipment and was scheduled to dovetail with snow removal operations. Typically, when snow removal was completed after a storm, the plows would be dropped from the trucks and the trucks used to haul sand to the road segment being built at that time. Because the height of embankment seldom exceeded 18 inches (see Figure 7) and the shoulder width was only 30 feet, the individual segments were usually completed in a few days in spite of haul distances of several miles.

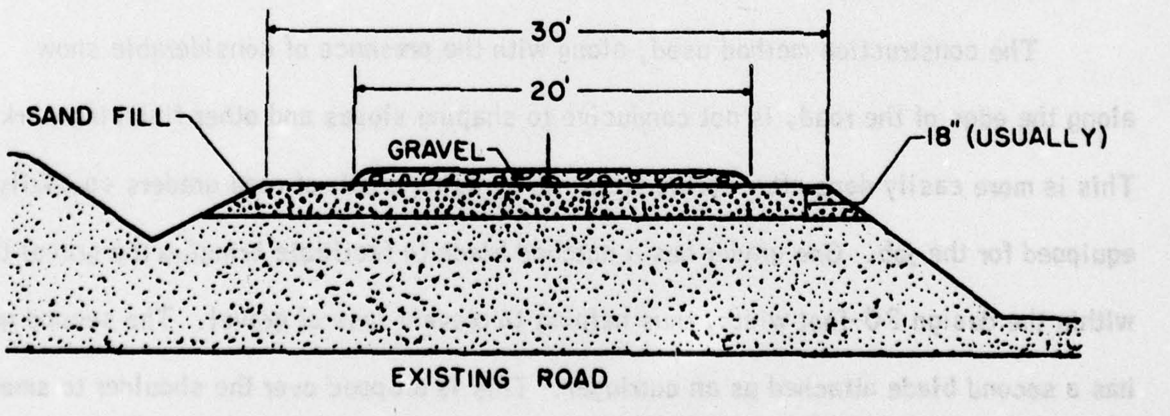

Figure 7 - Typical Section for Winter Fill Construction in Ontonagon County, Michigan

The construction procedure was straightforward. The trucks would dump sand on the existing roadway and rubber-tired dozer then would spread the sand and compact it. As the road had to be kept open to traffic, compaction had to be adequate to support wheel loads. Traffic that came along during actual construction was accommodated by the dozer operator, who would build a temporary ramp for the vehicles to climb onto (or descend from) the lift. This was done with little delay to either the using public or the construction operations. At the end of each day's work, a ramp would be built to handle traffic until construction resumed. The lift would freeze overnight, insuring stability.

Because the sand used in the lifts would not provide a suitable surface for traffic upon thawing, the project is not considered complete until gravel has been placed. This material is hauled from stockpiles, spread and compacted in a manner similar to the sand. However, the thickness of gravel is about 4 inches and its width is 20 feet. Therefore the volume per station is much less than for embankment material and the work can be done in a short period of time. This is critical, as the gravel must be placed before the spring thaw begins. With the gravel in place, no further construction work is done until the spring break-up period is over.

The construction method used, along with the presence of considerable snow along the edge of the road, is not conducive to shaping slopes and other finishing work. This is more easily done after spring break-up by using a pair of road graders specially equipped for the job. One grader has a notched blade to facilitate bringing the gravel to within the design 20-foot width, thus helping to prevent loss of gravel. The second grader has a second blade attached as an outrigger. This is dropped over the shoulder to smooth the slope. Usually two complete passes with this team of graders is sufficient to finish

the slopes and to reshape the gravel. With seeding and mulching of the slopes, the project is considered complete.

Although these embankments were not constructed under strict density control they may nevertheless be considered successful in that they have proven adequate for the low traffic volumes, were constructed at low cost, have permitted the relatively rapid upgrading of the county road system, and made effective use of the county's regular work force.

DISCUSSION

Construction Techniques

Specifications covering winter construction require that no frozen material be incorporated into the embankment core and that fill not be placed on soil containing more than 0.3 of a foot of frost. Consequently, winter construction generally results in considerable extra handling of soils, and much of this may involve ripping. Therefore, construction practices have been developed to minimize the amount of wasting and extra handling of the frozen soil.

One area of construction that can influence the effectiveness of winter operation is equipment selection and utilization. From observation at several borrow areas it appears that loading trucks with a front end loader is effective and efficient (see Fig. 8). Using a front end loader, it is possible to keep a deep working face and excavate below the level of frozen soil. This means there will be little waste or stockpiling of frozen soil. In fact, the layer of frozen soil over the working area may reduce additional freezing, and each day's work can begin with removal of the layer of frozen soil that developed along the face during the night.

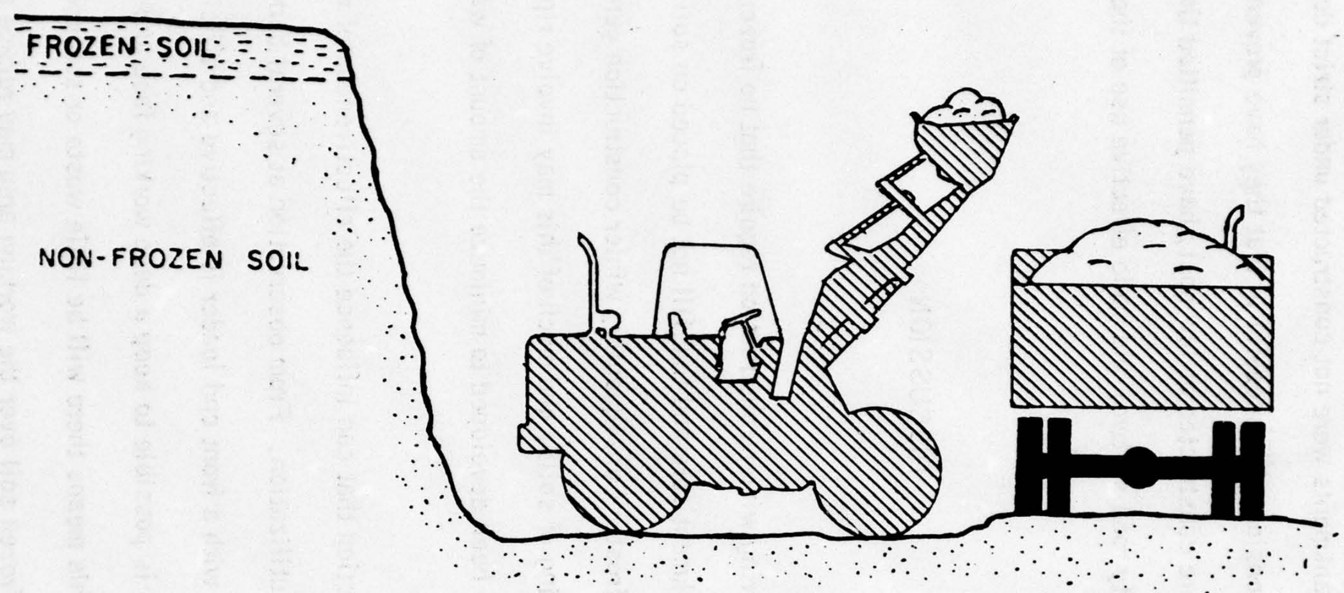

Figure 8 - A Deep Working Face in Borrow Pit Minimizes Frozen Soil to be Wasted

It also appears that available thickness of borrow material, ability of the equipment to work relatively high faces, and amount of overburden to be removed should also be considered when using front end loaders for borrow operations.

Scrapers can also be used effectively. On one of the projects, scrapers loaded ripped frozen soil with effort comparable to loading unfrozen soil. Careful planning by the contractor resulted in a low ratio of ripped frozen soil to nonfrozen soil. He planned his operations so deep cuts from relatively small areas could be taken out after each ripping operation, the area being limited to the amount of work that could be done in a single day. The corollary is that shallow cuts may not be well suited to winter work.

On the Marquette County project, a D8 dozer with attached hydraulically controlled ripper was used to rip the frozen soil. This tractor weighs about 62,000 lbs. including dozer blade and controls, and the ripper adds about 10,000 lbs. more. It has a ground contact area of about 5050 square inches, thus a contact pressure of about 14.25 psi. The length of track on the ground is 115 inches. This same type of machine was used to handle the frozen soil where it was dumped and spread. The compaction outside of the core was not regularly checked, so the results are known to be good only by subjective judgement.

On the Alger County project, the material placed outside the core was of two kinds. The first was frozen sand stripped from the previous day's construction. As the "core" concept means that only the core is expected to carry pavement loads, there is not so much concern for the material outside the core, and few tests were made. Again, considerable judgement was applied to determine adequacy of compaction. The second kind of soil was not frozen, but consisted of bouldery clayey soil which was placed outside the core because it was believed that it would be difficult to obtain good densities

due to the many boulders and cobbles in the soil. This material was reworked in the late spring to obtain better compaction while finishing the slopes. In this process, some of the largest boulders were worked out of the soil and pushed aside. Large rubber-tired dozers ("Michigan 280") were typically used for this work.

On the Ontonagon County projects a somewhat smaller rubber-tired dozer ("Michigan 180") was used for spreading and compacting the sand fill as well as the gravel which was placed just before the break-up began. This smaller machine was chosen by the County because it could manuever in smaller spaces and was otherwise better suited to the County's overall operations.

Embankments should be placed in such a manner that there is a minimum volume of soil to remove each morning due to overnight freezing. Usually this means using the ramp method of construction so that the embankment is brought up to final grade as it is built, rather than by horizontal layers as is often done in ordinary construction.

Suitability of Soils

Of all factors that might make winter earthwork feasible, soil type is most critical. The Michigan soil manual recognizes this and recommends each soil type as being either well adapted or poorly adapted to winter grading. Generally, cohesive soils are indicated as being poorly adapted because they have high amounts of moisture and are difficult or impossible to place at optimum water content. Granular soils are usually considered to be adaptable to winter grading and clean sands can be handled quite well as demonstrated on the observed projects. For example, on the Marquette County project, the average portion finer than the No. 200 sieve was 1 percent and the maximum was 2 percent, with 100 percent finer than the No. 10 sieve. The moisture content ranged between 2 and 6

percent. The sand on the Alger County project also average 1 percent finer that the No. 200, and 95 percent finer than the No. 40 sieve. As it came from a borrow pit that needed to be dewatered, it was essentially saturated at placement, but drained quite rapidly. Gradation curves for the soils at the Marquette and Alger County projects are shown on Figure 9.

The soils being placed on the Ontonagon County projects generally contained more fine material. The Simar pit was lowest at 2 percent fines, the Ontonagon pit had 6 percent, and the pit near Choate Road had 8 percent fines. All these materials were taken from borrow pits with loaders and trucks, so that the effect of the frozen crust was minimized. Typical gradation curves are shown in Figure 10.

Climatic Factors

Temperature is obviously one of the physical constraints. A general observation was that when the temperature was in the twenties there was little difficulty with most earthwork, provided reasonable methods were used. When the temperature was in the teens, there was a tendency for the projects to be shut down, and when the temperatures were in the single digits (or lower), the contractor usually would elect not to work.

The reasons for shutting down are based in part on the engineer's and the contractor's respective viewpoints on what is desirable. When temperatures are only slightly below freezing, the engineer perceives that he is getting good compaction; therefore it is at least permissible (and possibly desirable) from his viewpoint to continue. As air temperatures go below about +20°F, however, the engineer becomes concerned that the soil may be freezing before it can be adequately compacted. His problem is compounded by the relative difficulty of obtaining meaningful field compaction measurements. Lacking

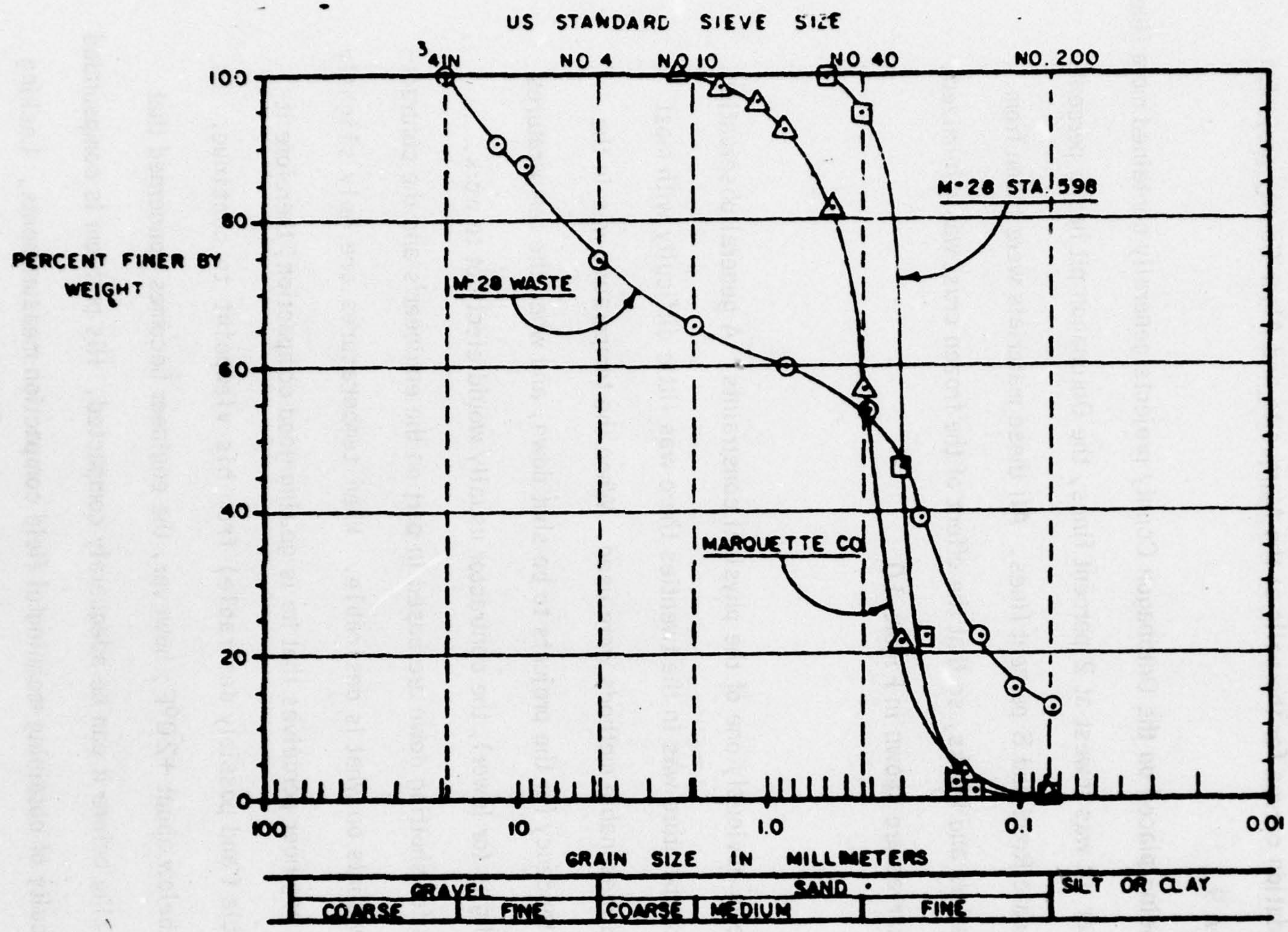

Figure 9 - Gradation Curves for Soils Used in Winter Construction, Alger and Marquette County Projects

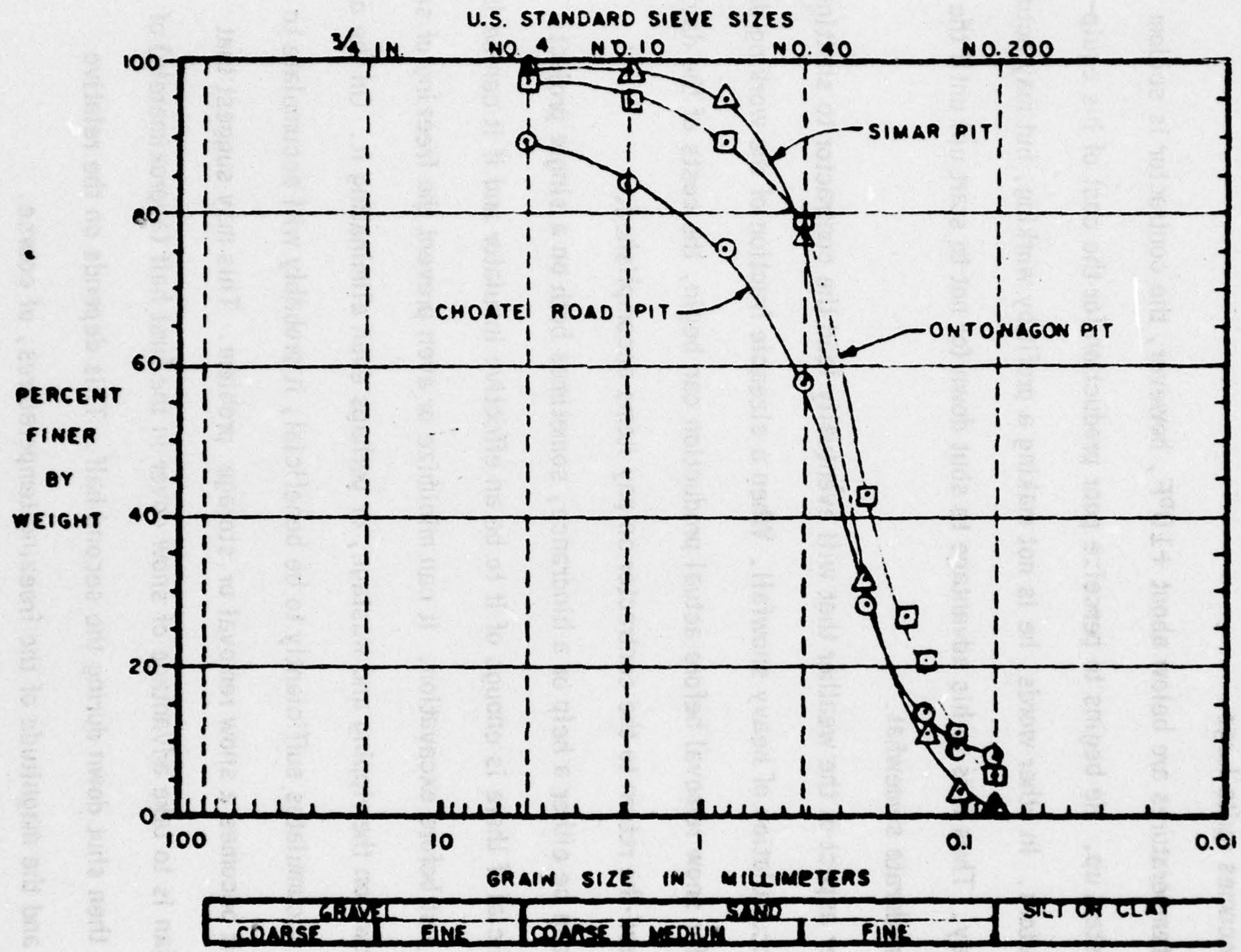

Figure 10 - Gradation Curves for Soils Used in Winter Road Construction, Ontonagon County

definite data to show that he is getting good compaction, he is inclined to shut the project down. (The contractor, however, may still view the work as profitable.) Also, heavy snowfall is a reason for stopping work as the probability of incorporating snow into the embankment becomes quite large.

When temperatures are below about +10°F, however, the contractor is seldom very eager to start up. He begins to perceive poor production for the cost of his equipment and operators. In other words, he is not making a profit by working, but may actually be losing money. Thus it is to his advantage to shut down (or not to start up) until the temperatures moderate somewhat.

Another aspect of the weather that will eventually lead the contractor to shutting down is the accumulation of heavy snowfall. When a sizeable fraction of the working day must be used for snow removal before actual production can begin, the costs of the day's work may exceed the return to the contractor on pay items accomplished.

Snow can be either a help or a hindrance, sometimes both on a single project. Snow is beneficial if there is enough of it to be an effective insulator and if it can be left in place until just before excavation. It can minimize or even prevent the freezing of soil, thus cutting down on the ripping and wastage, or perhaps even eliminating it. On the other hand, if snow accumulates sufficiently to be beneficial, it probably will accumulate to the point that it becomes a snow removal or storage problem. This may suggest that the optimum plan is to take advantage of snow cover in the first half (approximately) of the winter and then shut down during the second half. This depends on the relative depth of snow and the magnitude of the freezing temperatures, of course.

Institutional Factors

State specifications are intended to produce subbases that will have minimum settlement and other deformations affecting high-type paving. Thus they tend to be conservative with regard to winter earthwork construction, perhaps because both the engineer's and the owner's interests are at stake. Unofficial comments of highway engineers often indicate that they would rather not do winter earthwork, as they have had, or heard of bad experiences.

Contractors seem to be divided about winter earthwork. In addition to specification limitations, the contractor must consider the possibility of more equipment breakage and down time, the need for increased maintenance, additional safety problems due to slippery work surfaces, and the difficulty of maintaining a consistent schedule due to period of heavy snowfall or extreme cold. As a result of these factors, most contractors prefer to shut down earthwork operations for the winter.

On the other hand, the contractor must also consider the costs of penalties for not completing the project on time, or for overtime wages to insure that he does complete on time. Other factors, such as a desire to earn some income during the winter to offset equipment payments, and to hold key personnel, may also contribute to his decision to work during the winter.

A county highway department which does its own construction is in a different situation relating to winter earthwork, as it is simultaneously the owner, engineer, and contractor. Thus, the primary concern of the county highway department is to develop a road system to a reasonable design standard compatible with the traffic, at the lowest possible cost. In the case of Ontonagon County, a further objective is to keep their work force steadily employed. A general observation is that earthwork is a task that <u>can</u>

be done in the winter, while other work clearly can only be done during the summer. This does not apply to all counties, however. Inquiries to other county highway departments in the Upper Peninsula indicated that heavy snow could prevent effective work, or that other, unspecified conditions were not favorable to winter earthwork. Thus, it is clear that the decision to do earthwork in the winter should be made only after a careful study of all the factors that could make it difficult or that could contribute to its success.

ACKNOWLEDGEMENTS

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APPENDIX

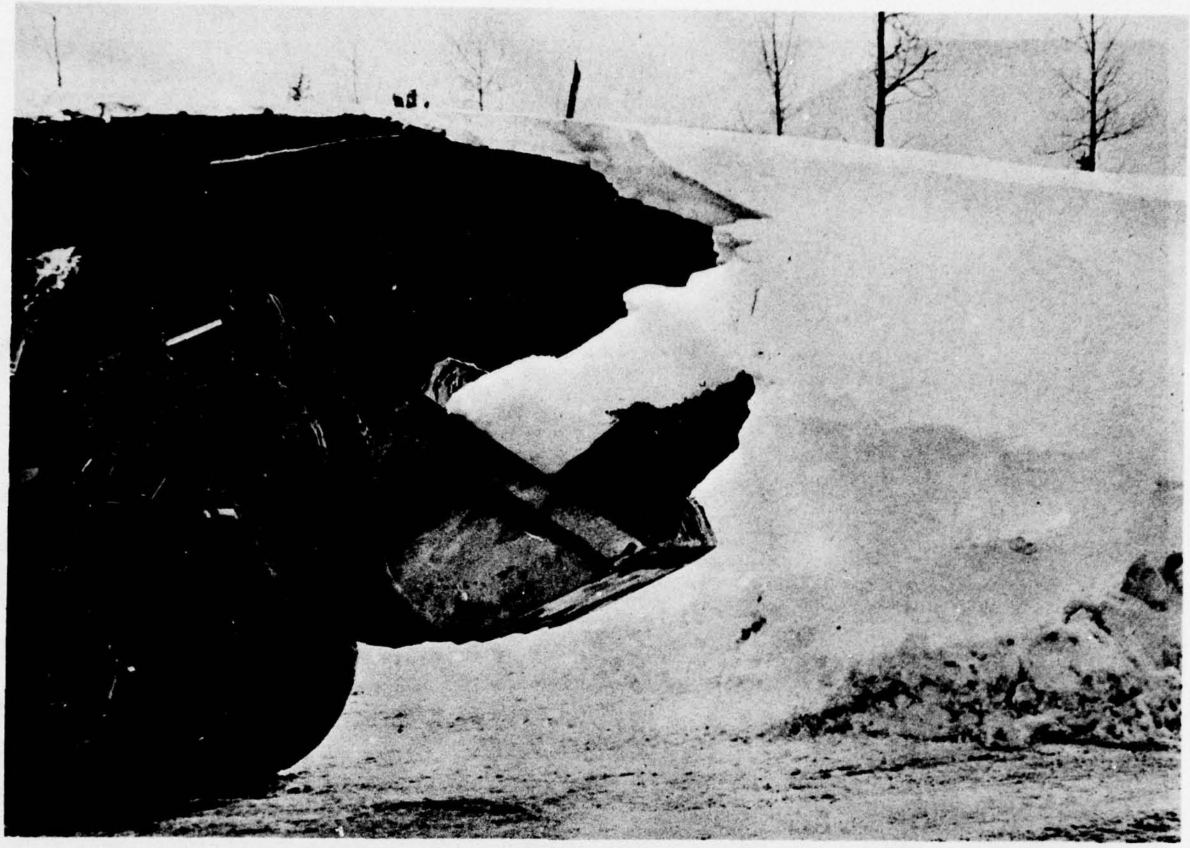
Photographic Record of Winter Earthwork Construction Projects

Part of the monitoring and observing of winter earthwork construction was to consist of a photographic record of each project. This appendix is a collection of black and white glossy prints intended to meet that requirement. The Ontonagon County project(s) received the best photographic coverage. The coverage of the projects in Alger and Marquette Counties is less complete because of the greater travel distance, scheduling difficulties, and camera failure. However, it is believed that this coverage illustrates the construction methods and problems adequately.

The photos are identified by number, county, and road or locality where appropriate. There are 20 photos from Ontonagon County, 8 from Alger County, and 4 from Marquette County.

1. Ontonagon County. Loader working in Simar pit. Note height of working face, and type of dump truck used for hauling.

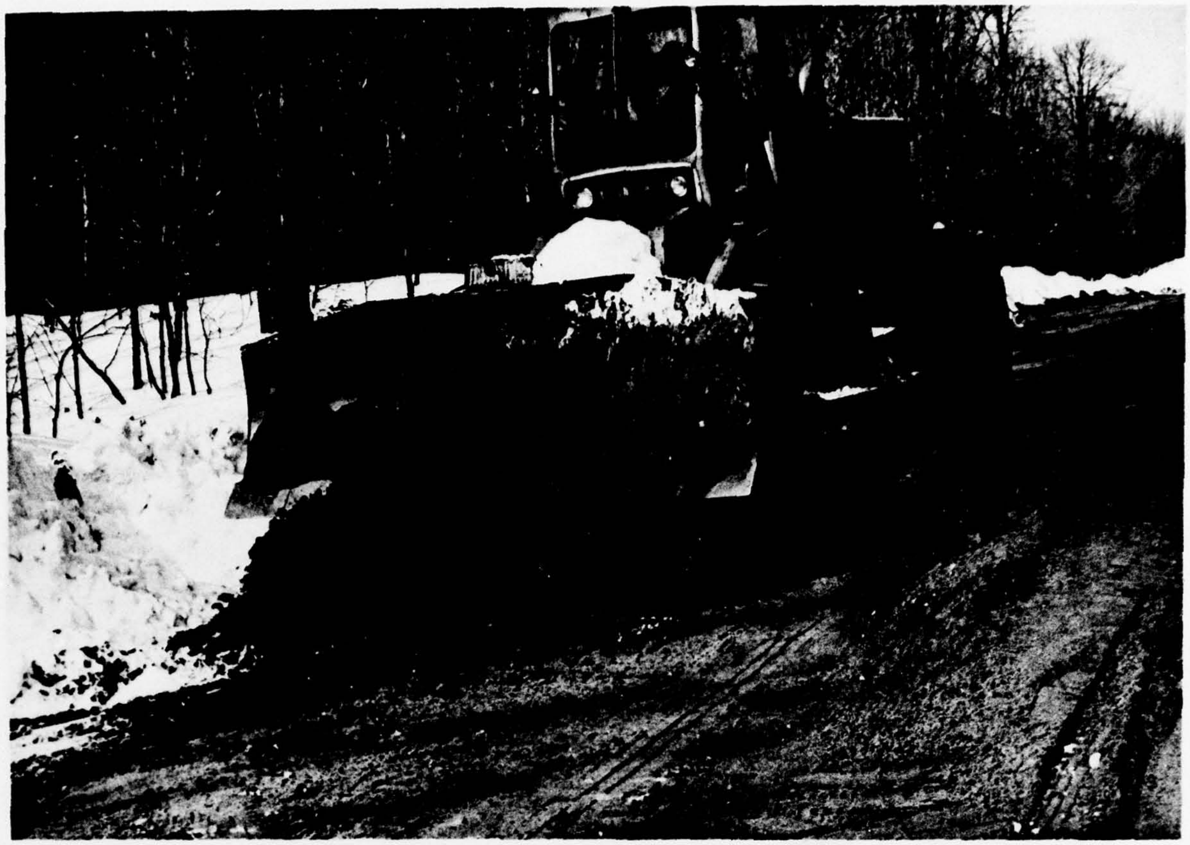
2. Ontonagon County. Simar Pit. Slab of snow-covered frozen soil has fallen into pit.



3. Ontonagon County. Simar Pit. Removal of frozen soil from working area to avoid placing it on the road fill.

4. Ontonagon County. Simar Pit. Pile of frozen soil which was removed from the loading area.

5. Ontonagon County. North Firesteel Road. *Spreading of fill with rubber-tired* dozer. Note ramp to accommodate occasional local traffic.

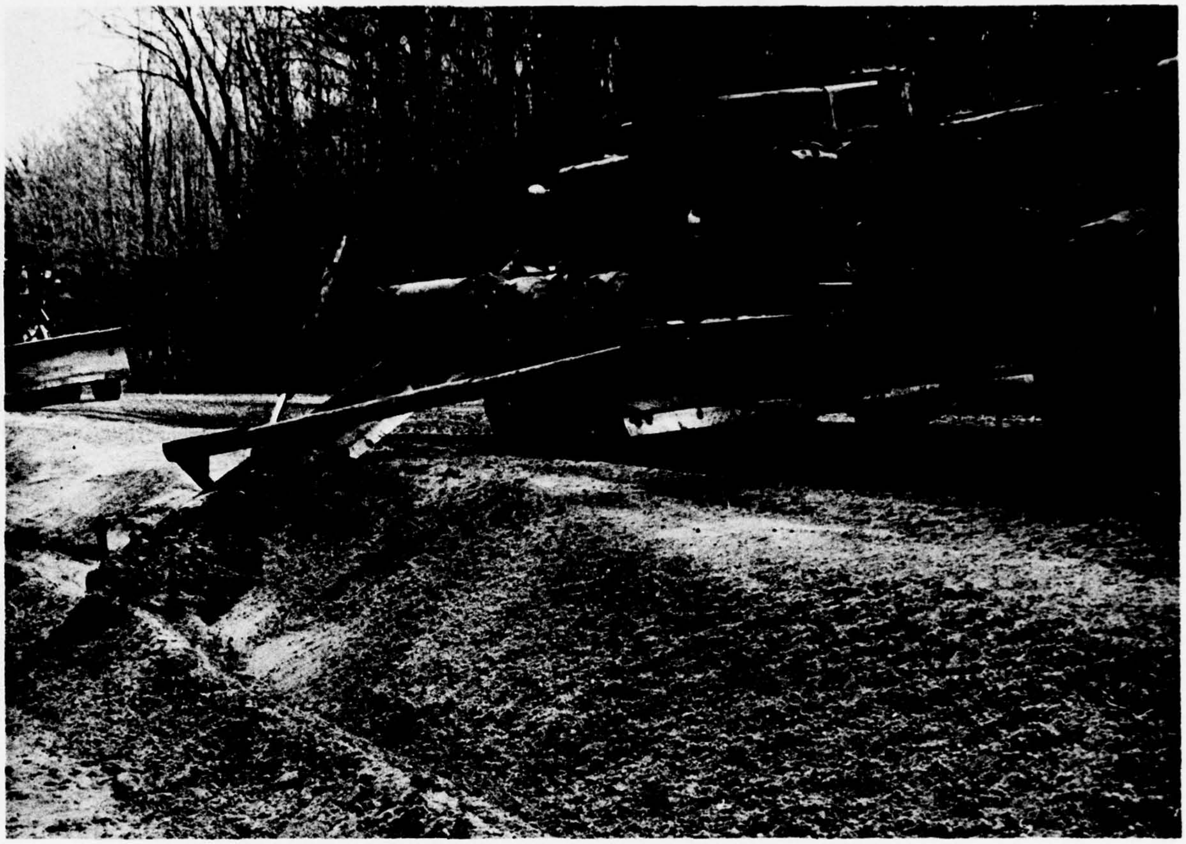


6. Ontonagon County. North Firesteel Road. Another view of spreading and compaction of fill.

7. Ontonagon County. North Firesteel Road. Back blading and final compaction at end of the working day. Low overnight temperatures freeze fill, creating stable roadway by the next morning.

8. Ontonagon County. North Firesteel Road. Sand fill will not bear traffic upon thawing, so gravel surfacing is placed before thawing begins. Gravel is hauled from stockpiles built up the previous summer. Note that considerable snow is included with the gravel.

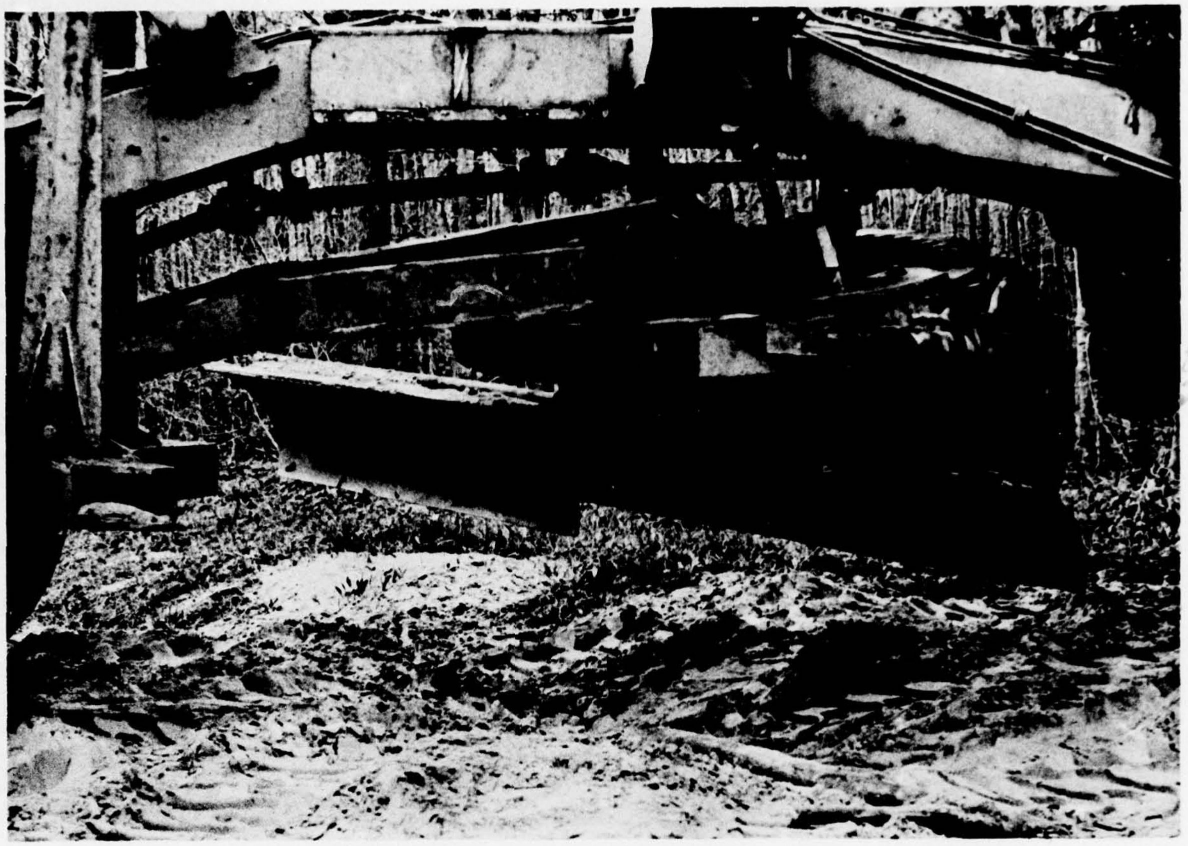
9. Ontonagon County. North Firesteel Road. Spreading and compaction of gravel with rubber-tired dozer.



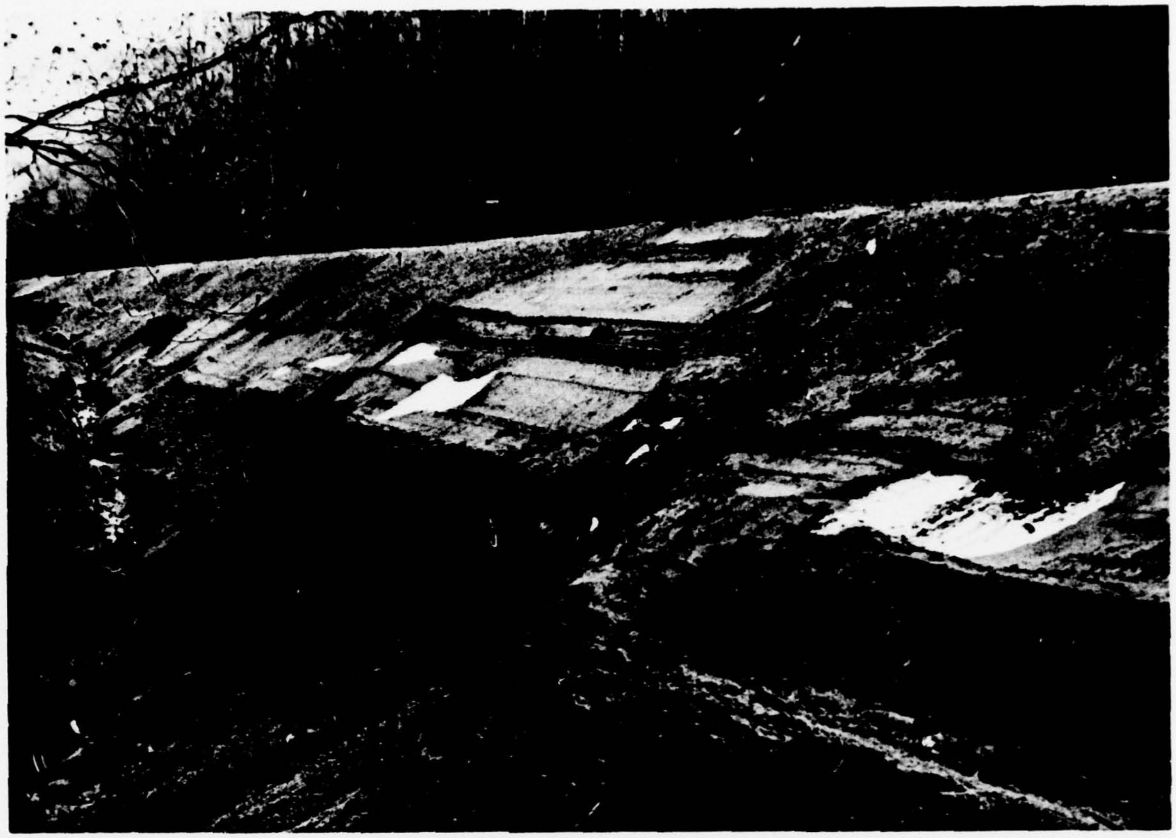
10. Ontonagon County. North Firesteel Road. Trimming and shaping of fill slopes after thawing is essentially complete. Grader with outrigger blade is leader in two-grader slope finishing team.

11. Ontonagon County. North Firesteel Road. Second grader in slope finishing team shapes shoulder of sand fill without disturbing gravel. The blade of this grader is specifically adapted to this purpose.

12. *Ontonagon County. North Firesteel Road. Another view of slope finishing grader team.* Shaping is considered complete after two passes of team.

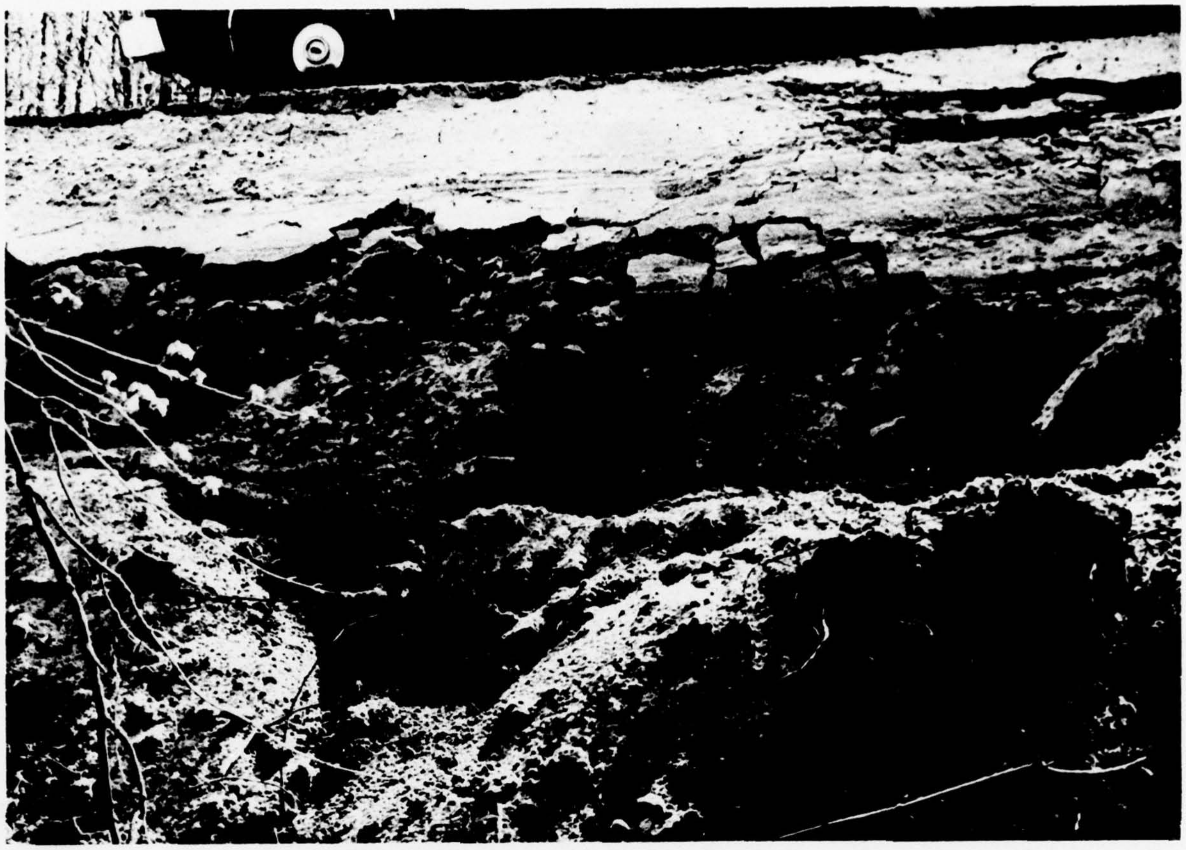


13. Ontonagon County. Detail of blade on second grader of slope finishing team. This arrangement permits shaping the shoulder of the fill without disturbing the gravel traffic course.



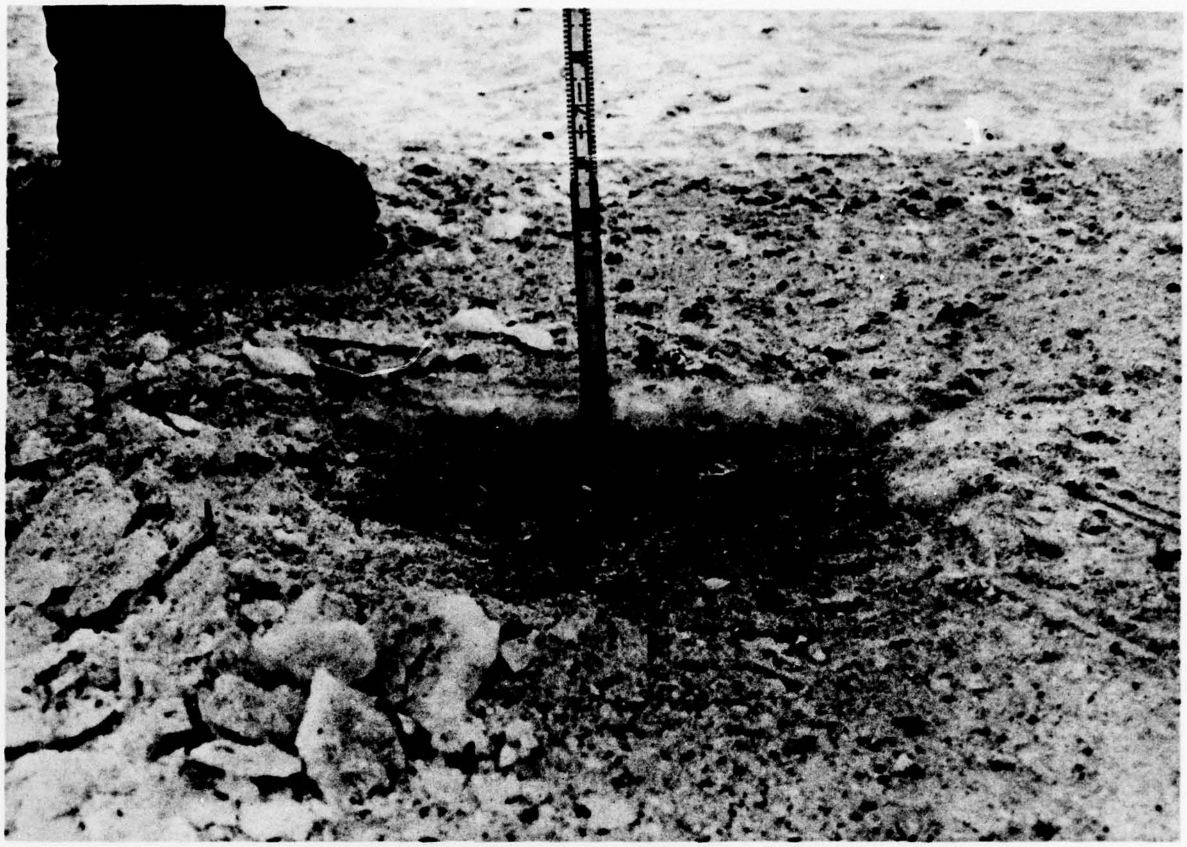
14. Ontonagon County. North Firesteel Road. Evidence that chunks of snow were inadvertently incorporated into slope of fill. Photo taken after slope finishing operation.

15. Ontonagon County. North Firesteel Road. Slumping of slope, probably due to thawing of frozen soil or incorporated snow. It should be noted that compaction of this part of the fill is difficult due to the construction methods.



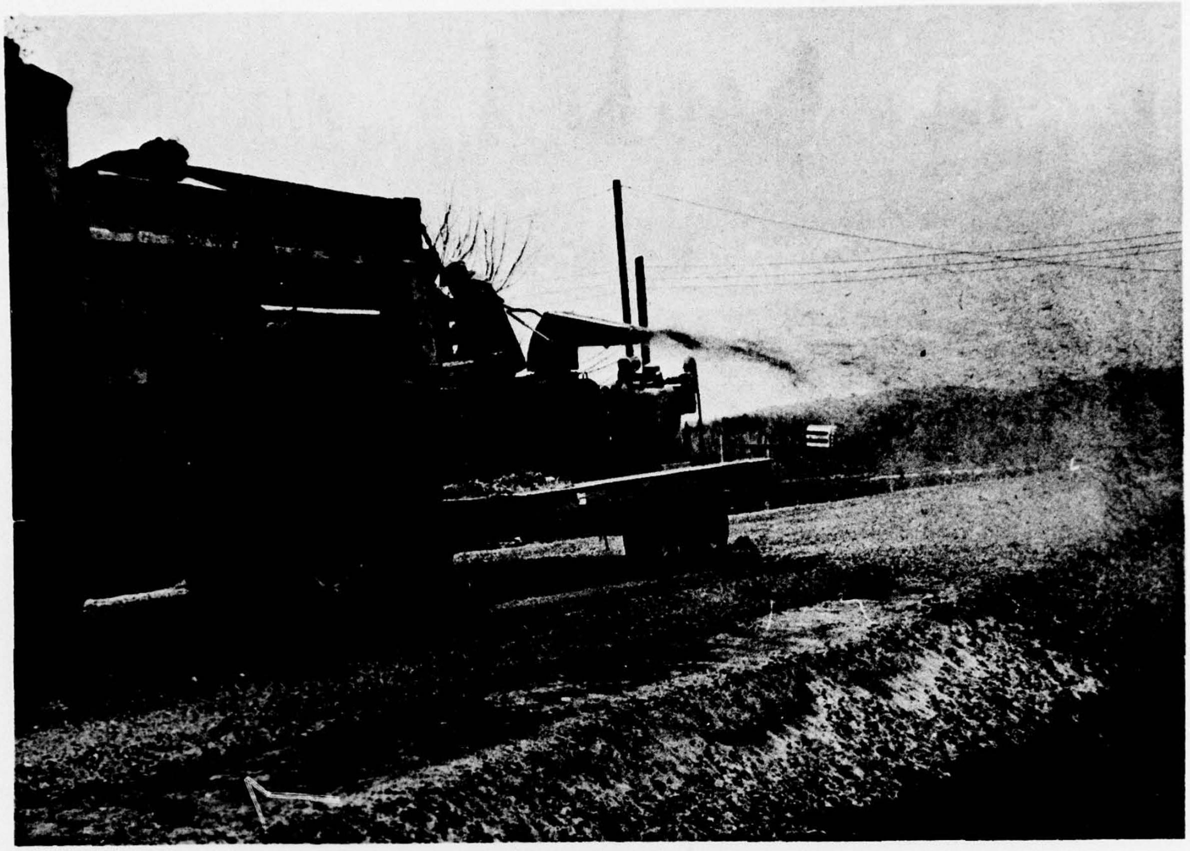
16. Ontonagon County. North Firesteel Road. Another example of slope slumping. In spite of its poor appearance, this slump is probably not very serious, considering the character of the road and the low traffic volumes it is expected to carry.

17. Ontonagon County. Wagner Road. General view of hauling, dumping, spreading and compacting.



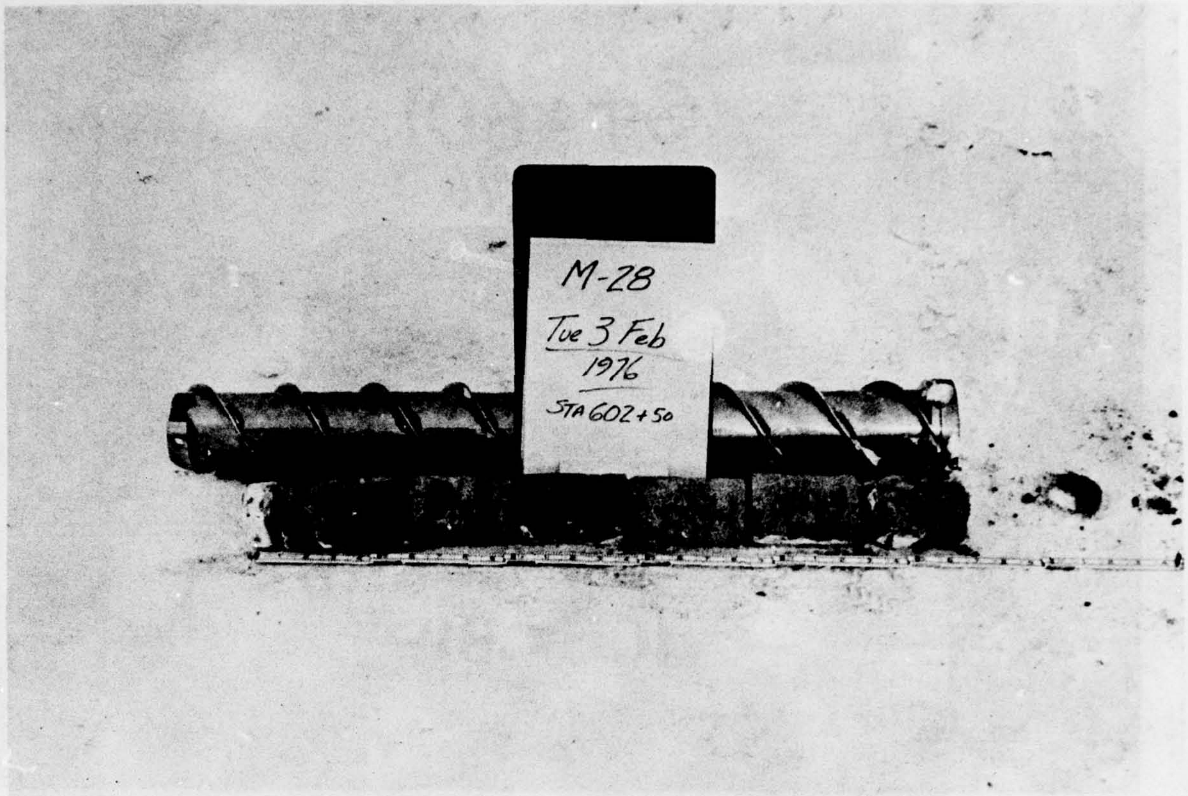
18. Ontonagon County. Cherry Lane. Sand fill was placed upon this 0.1 - foot layer of very compact snow on the existing road service.

19. Ontonagon County. Cherry Lane. Typical ramp constructed at end of each day's operation. Compacted sand freezes quickly enough that cars and small trucks have little difficulty travelling on fresh grade.



20. Ontonagon County. Typical mulching operation in late springtime. Mulch, consisting of chopped hay, is applied after slope finishing operation is complete. Seeds in hay germinate to provide grass cover for slopes.

21. Alger County. State Road 28. Although this photo was taken in June 1976, it illustrates the problem of a high ground-water table in the borrow pit which was one of the factors limiting the continuation of earthwork construction through the winter on this project.



22. Alger County. State Road 28. Core of frozen sand taken from embankment constructed earlier in the winter. Top of core (left end in photo) includes hard packed snow resulting from construction traffic and snow clearing operations. Photo also shows core barrel used with powered drive unit for coring.

23. Alger County. State Road 28. Close-up of core showing ice chip incorporated into compacted soil.

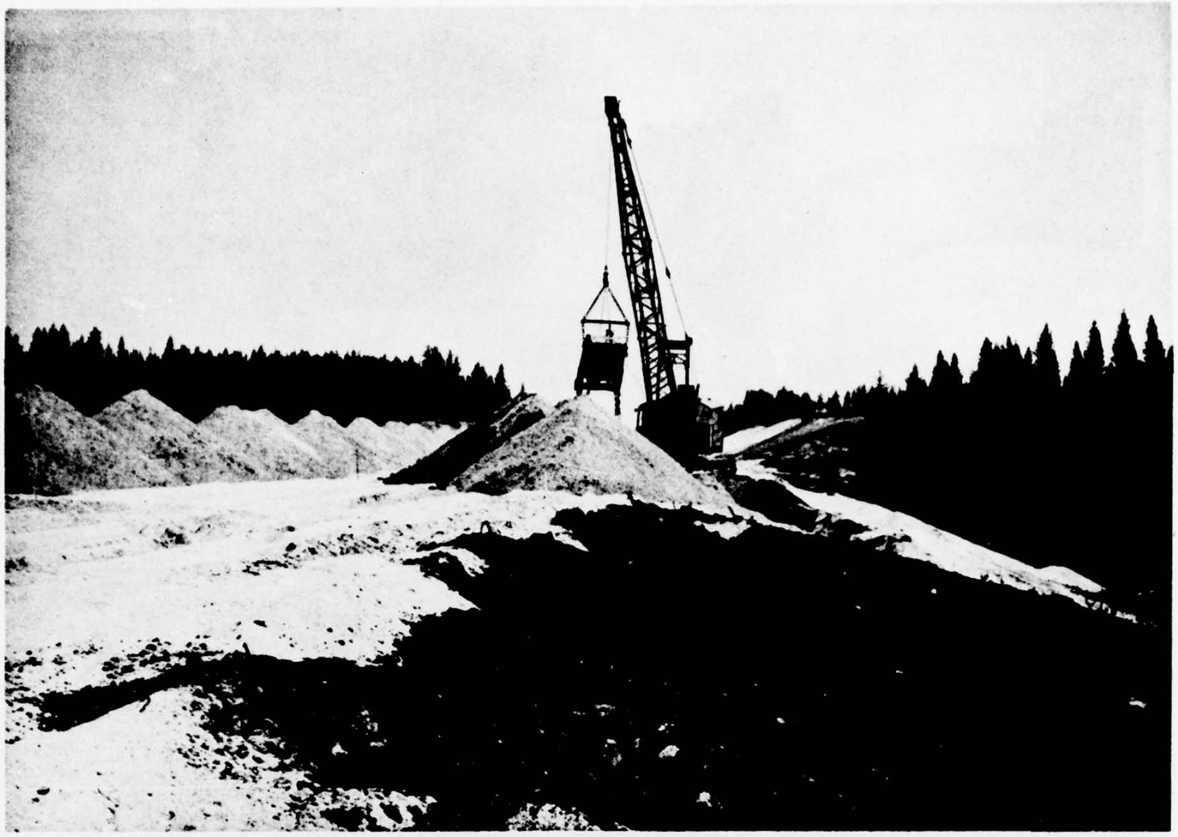
24. Alger County. State Road 28. Core samples like these were packed in snow and taken back to the laboratory cold-room. Here the in-situ dry density in pcf and the moisture content in percent were determined.

25. Alger County. State Road 28. Placing bouldery clayey soil in zone outside of structural core. Although this soil is not frozen, it was excavated, hauled and placed during the winter, and illustrates how frozen soil could be handled and utilized if necessary.

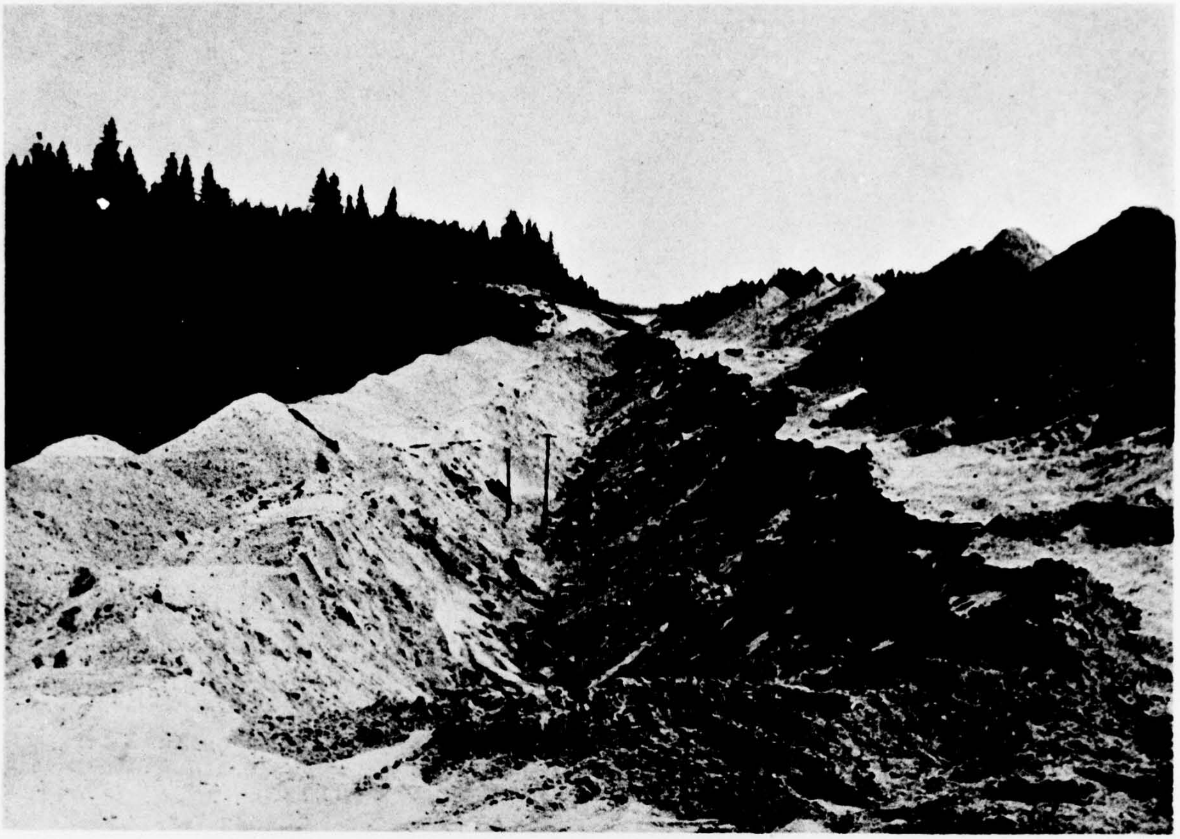
26. Alger County. State Road 28. Spreading bouldery clayey soil (see also Photo 25). Although this soil was not frozen during excavation and placement, the boulders can be considered to act like frozen soil chunks in the fill. Possibilities exist for the formation of large void spaces in the fill.

27. Alger County. State Road 28. This photo, taken in summer, illustrates the use of a structural core of sand in the embankment, flanked by less desirable soil in the slope zone. This bouldery clayey soil was placed unfrozen during the winter (see Photos 25 and 26), subsequently froze, and then was compacted and shaped after thawing. Photo taken in June 1976.

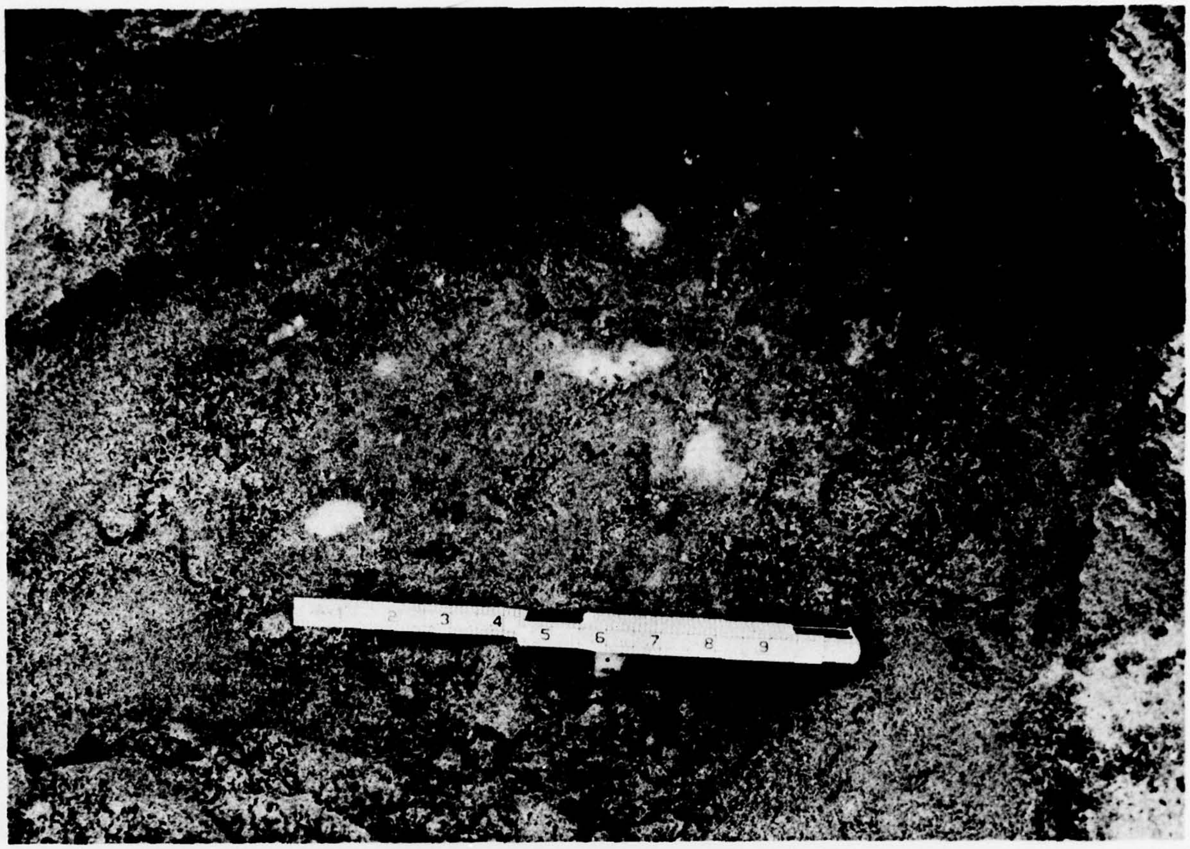
28. Alger County. State Road 28. Large rubber-tired dozer compacting soil in slope zone outside of structural core of sand. See also Photos 25, 26 and 27. Photo taken in June 1976.



29. Marquette County. County Road 553. Dragline excavating slope zone to uncover frozen soil. Photo taken in June 1976.



30. Marquette County. County Road 553. Appearance of slope after dragline excavation. Note soil auger (approximately five feet high) standing in trench. June 1976.



31. Marquette County. County Road 553. Frozen soil found at bottom of trench. June 1976.

32. Marquette County. County Road 553. Bulldozer backfilling trench (see Photos 29, 30 and 31) and recompacting slope zone after all frozen soil had melted. Photo also shows ripper which was used to rip frozen soil for excavation by scrapers during previous winter.